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TECHNICAL MEMORANDUM (NASA) 22

POSSIBLE METHODS FOR USSR-VLF NAVIGATION RECEIVERS

A brief study of the USSR-VLF navigation system indicates that very low-cost digital techniques might be applied to receiver systems. The transmitted signal format is of interest for application to other VLF systems in the future. Some possible circuits for simplified receiver processors are presented.

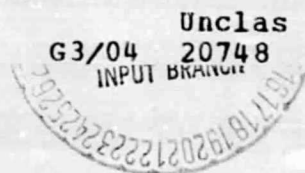
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I. INTRODUCTION

The USSR has a VLF navigation system similar to OMEGA. Beukers^[1] has reported some information on the signal format, frequencies used, and the probable radiated power levels. From this data it appears possible to derive receiver operation modes and some implied reasons for the unique choice of the time-multiplexed frequency time base used. Of interest are receiver methods requiring processor gate complexity similar to a digital wristwatch including the use of mass-produced low frequency quartz crystal reference oscillators. The stability required of the local reference oscillator is probably much less critical than for other VLF receivers because of the signal format. One conclusion is that USSR-VLF receivers might be fabricated at quite low cost making it possible for all persons in remote areas each to have his own private positioning aid. Further study of the actual transmitted signal format is warranted. While the nature of this memorandum is speculative because of the lack of confirming data, the receiver method proposed has evolved from related principles which have been applied to the operating OMEGA-VLF navigation system.

II. SIGNAL FORMAT

The precise nature of the signal format is uncertain but it is something like that illustrated in Figure 1. This was obtained by a careful study of Beukers measurements and comments (particularly Figures 16 and 17 of Reference [1]). Of interest are two factors:

- (1) The master station is always transmitting simultaneously in one of the nine uniform length 0.4 second time slots when either of the slave stations is on for the 11.095 KHz and 14.881 KHz combination;
- (2) The choice of frequencies used is very convenient in that the highest and lowest have a 4/5 ratio as well as a unique property of mixing with a single binary local oscillator frequency (2^n Hz) to produce low integer count ratios, i.e., 1/4, 1/16, etc.

As an aid to making it possible to use simple receiver methods the USSR has implemented the transmitters with high radiated power capabilities on the order of 100 kw which places much less strain on the receiver-processor for detecting signals buried in the atmospheric noise. Still another advantage of this format is a self-calibrating feature where the identification of the master station is obvious and a built-in propagation error correction is possible because of the use of two frequencies from the same master station which are on simultaneously during one of the 0.4 second time slots. Beukers has suggested that the other important feature here is the possibility of using the phase shift of the three segments of the master transmission to provide phase correction to the slave station transmitters as needed.

III. BINARY CLOCK MIXING METHODS

A digital superheterodyne receiver method has been devised for OMEGA-VLF use.^[2] The advantage of this method is that the local reference clock oscillator frequency can be the same order of magnitude as the signal frequency and is chosen as a binary number such

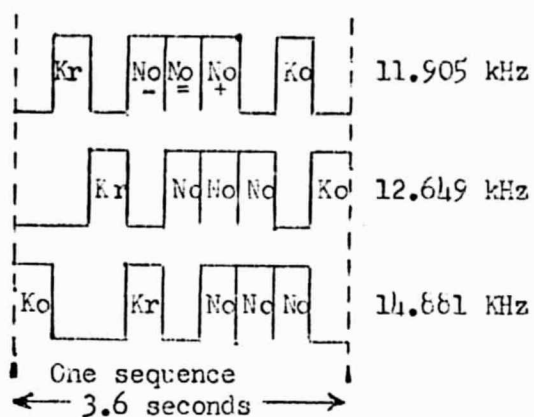


Figure 1. Probable USSR-VLF System Format.

as 2^{15} Hz which provides a convenient receiver time base. Figure 2 is a table of the intermediate sequences generated when the nearest lower binary frequency is mixed in successive steps until a common local oscillator results in a simple binary intermediate output ratio. (Sequence as used here implies the number of positive zero crossings per second, usually measured in ZPS or zero crossings per second). The highest and lowest USSR-VLF system frequencies of 14.881 and 11.905 KHz are unique in that successive digital mixing results in output measuring ratios of 1/16th and 1/4th with a 512 Hz local oscillator. The use of a common clock for both signals transmitting simultaneously mostly eliminates the clock offset error problem common with OMEGA measurement systems, and a highly stabilized quartz crystal oscillator is not required. The 4/5 transmitter frequency ratio results in a simultaneous pair 59.525 KHz lane of 2.5 km on the station pair baseline.[3] 1/16th of this lane is 0.15 km which is a conveniently low number for direct digitizing distance traversed intervals.

Further inspection of Figure 1 shows that immediately before and after each slave is measured simultaneously with respect to the master, the master-master correction for clock updating and automatic synchronization of the phase difference counter is possible. Because the local clock is never very far away from being synchronized with respect to the master-master time slot, it should be possible to accumulate 20 X multiples of the shorter lane equivalent to the interesting difference frequency lane of 50 km at $14.881 - 11.905 = 2.976$ KHz. (A lane in these hyperbolic measurement systems is 1/2 wavelength measured on the station pair baseline and referred to the common measurement frequency.)

Figure 2 may be further simplified with a single local oscillator at 512 Hz as the common mixing frequency since a D type flip flop mixer is also sensitive to all the higher integral harmonics of the lowest LO signal used. Thus a possible input mixer circuit for the two USSR channels of 11.905 KHz and 14.881 KHz is illustrated in Figure 3. The output of each mixer is a bit sequence something like that shown where the ratio between the bit rate at 11.905 is 1/4th that at 14.881, when the two signals are in phase at some arbitrary starting point. Every time the receiver moves 0.15 km along the station pair baseline, the position of these pulse trains with respect to each other will shift one of the smaller intervals at the 14.881 KHz output, and correspondingly every time the receiver moves 4X this distance, the pulse trains will move one of the larger intervals at 11.905 KHz. From this output it appears possible to devise a relatively simple measuring apparatus which will count in binary intervals for the fine resolution of 0.15 km and accumulate the total count in groups of 4 to measure larger intervals. The local clock is synchronized to the master station pair between each master-slave combination and will give a relatively constant correction reading depending on the phase shift of the segments of the master-master segment and a propagation factor.

We have not worked out the complete details of the measurement system but suggest that variations of the above technique can be made to work with relatively simple digital counter hardware.

IV. USSR-VLF RECEIVER CLOCK SYSTEM

To further illustrate the simplicity of a USSR-VLF navigation aid device we have devised a clock circuit involving only a few CMOS chips and a low-frequency crystal

INPUT FREQUENCY	11.905 KHz	14.881 KHz
1st mixer	$\frac{-8.192}{3.713} (2^{13}\text{Hz})$	$\frac{-8.192}{6.689} (2^{13}\text{Hz})$
2nd mixer	$\frac{-2.048}{1.665} (2^{11}\text{Hz})$	$\frac{-4.096}{2.593} (2^{12}\text{Hz})$
3rd mixer	$\frac{-1.024}{641} (2^{10}\text{Hz})$	$\frac{-2.048}{545} (2^{11}\text{Hz})$
4th mixer	$\frac{-512}{129} (2^9\text{Hz})$	$\frac{-512}{33} (2^9\text{Hz})$
Output Ratio	$\frac{129}{512} \approx \frac{1}{4}$	$\frac{33}{512} \approx \frac{1}{16}$

Figure 2. Binary Mixing of USSR-VLF Frequencies.

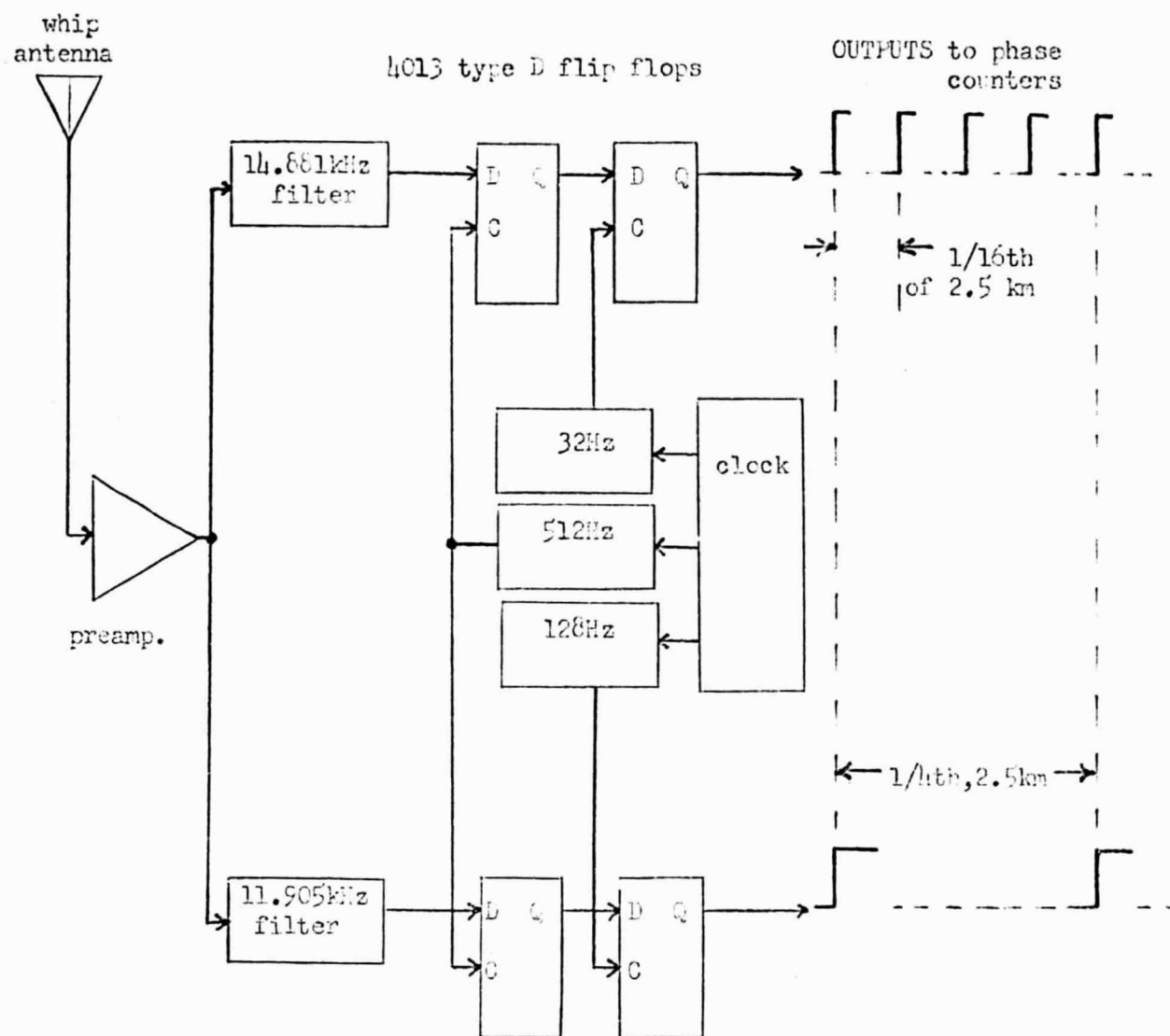


Figure 3. USSR-VLF Receiver Front-End.

oscillator as in Figure 4. The clock circuit provides the binary reference frequencies for the phase measurement of Figure 3 and the selected time slot intervals for the three station chain. The clock starts out with a quartz crystal which is presently a stock item used in some timing systems. (STATEK model SX-1V 40.960 KHz at about \$5.40 each in lots of 1 to 24.)

V. RECEIVER FRONT-END

The propagated radio signals may be received on a very short whip antenna (< 1 meter) driving a JFET bandpass filter-amplifier and be split into two channels for very narrow band filters using other low-cost quartz crystal resonators. It has recently been discovered that single crystal resonators combined with low-cost "automotive type" quad operational amplifier can provide excellent VLF receivers for the front-end components.^[2] While 14.881 and 11.905 KHz crystals are presently not available as stock items (so that a USSR receiver of simple design could be checked out by Western observers) there is no reason why they could not be readily available in quantity when the initial set-up charges and frequency trim facilities have been provided. (STATEK model SX-1N quartz filter crystals require a minimum set-up order of about \$200 for non-stock frequencies in the 10 KHz to 100 KHz region with a 20 week delivery delay.) These crystal filter units may be obtained with a Q of the order of 2500 which provides a bandwidth of about 4 Hz or about twice that required to pass a 0.4 second signal duration pulse and still have the signal recognizable in the output. This ultra-narrow bandwidth is advantageous over other front-end methods in providing excellent low-level signal reception with a minimum of hardware.^[2]

VI. CONCLUSIONS

It appears possible to design a very low-cost (under \$500 in production quantities) signal processor for the USSR-VLF navigation system, if we understand the nature of the system format correctly. The transmitter signal format is unique in that it appears to have been selected with a view toward low-cost receiver processors.

VII. RECOMMENDATIONS

A more detailed study and hardware implementation of an actual working model of this receiver is suggested to uncover any pitfalls in the design proposal here and to test the method on actual USSR-VLF signals. An advantage of a continued study would be the evolution of design information which could be of value for use in other VLF navigation systems for aircraft, boats, and backpacking.

VIII. ACKNOWLEDGEMENT

The partial support of the National Aeronautics and Space Administration for this brief study is acknowledged. A purpose of the work has been to seek information to aid in the application of VLF navigation techniques for the general aviation community. The help of Professor G. E. Smith in pointing out some of the simultaneous pair measurement problems is appreciated.

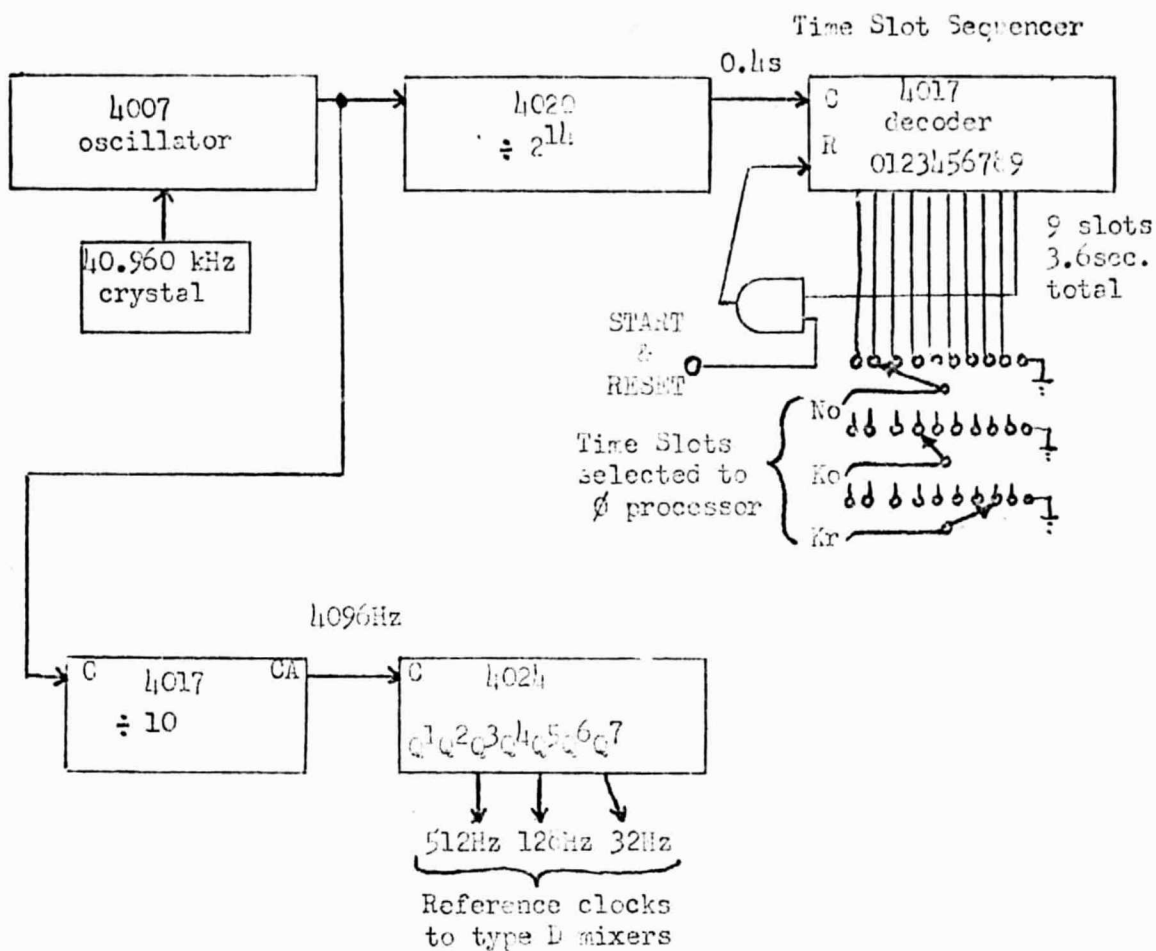


Figure 4. USSR-VLF Receiver Clock.

IX. REFERENCES

- [1] Beukers, J. M., "A Review and Applications of VLF and LF Transmissions for Navigation and Tracking", J. Inst. of Nav. 21, No. 2, pp. 117-133, Summer 1974.
- [2] Burhans, R. W., "The Mini-O, A Digital Superhet, or a Truly Low-Cost Omega Navigation Receiver", NASA CR-144923, OUTM-20(NASA), Avionics Engineering Center, Ohio University, Athens, Ohio, 45701, November 1975.
- [3] Burhans, R. W., "Simultaneous Master-Slave Omega Pairs", IEEE Trans. Aero. and Electronic Syst., AES-10, No. 6, pp. 895-898, November 1974.